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Contact Lens Use in the Civil Airman Population

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16. Abstract

INTRODUCTION: Since 1976, the use of contact lenses by civilian pilots has been permitted to correct distant vision for obtaining a Federal Aviation Administration (FAA) aeromedical certificate. Although contact lens technology has advanced dramatically in recent years, the aviation environment may still have adverse effects on contact lens performance in some flight situations. This study examined the civil airman population's experience with contact lens use for a 30-year period (1967-97). The information will help guide future medical certification decisions, policy revisions, and education safety programs for aeromedical and flight crew personnel. **METHODS:** The FAA's Aerospace Medical Certification Division provided population totals for 1 January 1967 through 31 December 1997 of airmen who carried a pathology code for contact lens use (code 161) or orthokeratology (code 158). These data were stratified by class of medical certificate and age. Prevalence rates were calculated using the population frequencies from the annual Aeromedical Certification Statistical Handbook (AC 8500-1). A search of the National Transportation Safety Board (NTSB) and FAA databases was performed to determine if contact lens use had contributed to any aviation mishaps (accidents or incidents). **RESULTS:** The prevalence of contact lens use grew faster for first-class medical certificate holders (1.6/1,000 to 32.3/1,000 airmen) and airmen $\geq$ 40 years of age (3.7/1,000 to 34.2/1,000 airmen) during the study period. The frequency of airmen with orthokeratology increased by 23 times in a 10-year period. Reports from five aviation accidents and one incident suggested that contact lens use was a contributing factor in the mishap. **CONCLUSIONS:** Professional pilots and older airmen are more inclined to use contact lenses to satisfy the aeromedical vision standards. Contact lenses can be a liability in some flight situations but have performed well for the majority of aviators. The increasing use of contact lenses by airmen and the rapid changes in contact lens technology warrant monitoring to ensure continuing safe use in the aviation environment.

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Contact Lens Use in the Civil Airman Population

INTRODUCTION

Vision is the most important of the senses used by pilots while operating an aircraft. Over 80% of all information a pilot needs to operate an aircraft safely is obtained through the eyes (1). Without good vision, the pilot would be unable to maintain spatial orientation, making flight difficult, if not impossible.

The Federal Aviation Administration (FAA) is responsible for the medical certification of all civilian airmen in the United States. Civil aviators must hold an FAA pilot's license and maintain a current medical certificate of the appropriate class to legally perform duties associated with that class of certificate. Medical standards for pilot certification, which include vision standards, are listed in Title 14 of the Code of Federal Regulations (CFR) Part 67, §67.121.309(d) (2). There are three classes of medical certification for civilian pilots. Medical and vision standards are more stringent for airline pilots (first-class) than for commercial pilots (second-class) or private pilots (third-class). In general, the standards for the three classes of medical certification are related to the physical and technical requirements necessary to safely perform the duties for a particular class of flight. The vision standards for the three classes of certification are summarized in Table 1. Approximately 56% of all active airmen rely on some form of ophthalmic correction to meet the visual requirements for an FAA medical certificate (3).

Prior to 1976, civilian airmen were not allowed to use contact lenses while flying unless the FAA had issued a waiver, i.e., Statement of Demonstrated Ability (SODA), authorizing their use. Since 21 December 1976, Amendment 67-10 to the CFR has permitted the routine use of contact lenses to satisfy the distant visual acuity requirements of Part 67, which eliminated the SODA process in most instances.

The FAA has performed several epidemiologic studies that investigated the possible association between contact lens use and aviation accidents. In a 1975 study, Dille and Booze found this association to be only marginally significant ($p < .10$) (4). A follow-up study in 1976 found the use of contact lenses was associated with a significantly higher number of aviation accidents ($p < 0.01$) (5). However, in contrast to the previous studies, a 1979 study of general aviation airmen with accidents determined that contact lens

TABLE 1. Vision standards as listed in Part 67.103, .203, .303 of the Federal Aviation Regulations, revised September 16, 1996 (2)

Medical Certificate Pilot Type	First-Class Air Transport Pilot	Second-Class Commercial Pilot	Third-Class Private Pilot
Distant Vision	20/20 or better in each eye separately, with or without correction		20/40 or better in each eye separately, with or without correction
Intermediate Vision	20/40 or better in each eye separately (Snellen equivalent), with or without correction at age 50 and over, as measured at 32 inches		No Requirement
Near Vision	20/40 or better in each eye separately (Snellen equivalent), with or without correction, as measured at 16 inches		
Color Vision	Ability to perceive those colors necessary for safe performance of airman duties		

wearers had less than average accident involvement (6). Since the existence of an association between contact lens use and aviation accidents has been inconsistent, contact lens use remains an acceptable form of vision correction for civil airmen (7). However, a recent aviation accident in which the use of monovision contact lenses was determined to be a contributing factor in the mishap has rekindled the debate on the acceptability of contact lenses in the aviation environment (8).

Contact lenses have changed dramatically over the last 30 years. Lens technology has evolved to include materials that allow more oxygen permeability, thinner lens designs, hydrophilic (soft) lenses (that can be worn for an extended period without removal), and frequent replacement and disposable contact lenses. Specialty lenses are now available to correct for presbyopia. Also, the practice of orthokeratology, which uses contact lenses to reshape the cornea and reduce refractive error, has flourished with the development of new rigid oxygen permeable materials and improved lens designs.

Advances in aviation technology have made modern aircraft much more sophisticated. The traditional analog-type display (an alphanumeric dial surrounding a pointer) is becoming an oddity on the instrument panel of most modern aircraft. The "glass cockpit," which describes the latest generation of aviation instrumentation, is becoming increasingly common in modern aircraft. Instruments and displays have changed radically with advances in microcomputers, liquid crystal displays, light emitting diodes, cathode ray tubes, heads-up displays and global positioning satellite technology. These changes provide more flight information to the pilot and enhance aviation safety. However, multiple instruments and technology can increase the visual workload, making visual tasks more difficult, depending on the choice of refractive correction used.

Contact lenses have several inherent advantages over spectacle correction for pilots. These include: more natural vision, full field of vision, no lens fogging or water droplet accumulation, less discomfort due to weight, and no annoying obstruction from the frame or distracting reflection from the lenses. In addition, contact lenses are generally more compatible with protective breathing systems and communication devices than spectacles. Military pilots have used contact lenses in rugged wartime conditions and have reported them to be operationally superior to spectacles (9).

However, pilots can experience problems with contact lenses while flying. Contact lenses may become dislodged during aerobatic maneuvers; visual performance decrements have been reported in some aviation-related physiologic environments (e.g., hypoxia, hypobaria, low relative humidity) (9,10,11,12); and irritation can occur from blowing air while using full-face protective breathing apparatus. Additional demands on accommodation, inherent to contact lens use, especially by presbyopic airmen, can compromise flight operations. Furthermore, contact lenses have caused injuries such as contusions, foreign body abrasions, and lacerations (13).

The present author's last study of contact lenses in the civil airman population reviewed their use during the period from 1967 to 1987 (7). To guide future medical certification decisions, policy changes, and education safety programs for aviation personnel who use contact lenses, a retrospective epidemiological study on all active airmen was performed for the period 1967 to 1997.

METHODS

The FAA's Aerospace Medical Certification Division provided data for airmen that carried the contact lens pathology code 161 for each year starting in 1967 and ending with 1997. The Vision Research Team extracted frequency totals from this data by sampling every 5 years beginning with 1967 and ending with 1997. These totals were stratified by issued class and age of the year samples. (Note: Prior to Amendment 67-10 to the CFR, effective December 21, 1976, airmen using contact lens correction were assigned pathology code 161 and were required to obtain a waiver issued by the Aerospace Medical Certification Division, a part of the Civil Aerospace Medical Institute in Oklahoma City, Oklahoma. Use of contact lenses to correct distant vision is no longer considered a pathology and will not elicit a denial for a certificate. Despite the change in 1976 of CFR Part 67, the pathology code is still assigned to medical records, if the Aviation Medical Examiner (AME) notes on the medical form that the pilot uses contact lenses (14).) Data was also provided for airmen with orthokeratology (pathology code 158) for each year starting in 1987 and ending in 1997. (Note: A pathology code for orthokeratology was not assigned prior to 1 January 1987.) A similar stratification was performed for frequency totals of airmen with pathology code 158 by year and class.

Prevalence of contact lens use per 1,000 airmen, by class of medical certificate and age, was calculated using the total civil airman population frequencies extracted from the annual issues of the Aeromedical Certification Statistical Handbook (15). (Note: The 1967 data for airmen with pathology code 161 reported a different total frequency in the class category than was reported in the age category. The unequal frequencies in 1967 are presented for the sake of completeness. All frequencies in other years of the study were equal for both variables.)

The National Transportation Safety Board (NTSB) Accident/Incident Database and FAA Incident Data System were queried for the period 1988-98 (Note: Although the NTSB database has existed since 1983, the FAA Incident Data System was not established until 1988.). All reports that mentioned contact lens use were reviewed to determine whether these devices might have contributed to any aviation accident or incident.

RESULTS

The prevalence of contact lens use in the civil airman population by class of medical certificate is presented in Figure 1. First-class medical certificate holders had the fastest growth in contact lens use during the study period (1.6/1,000 to 32.3/1,000 airmen).

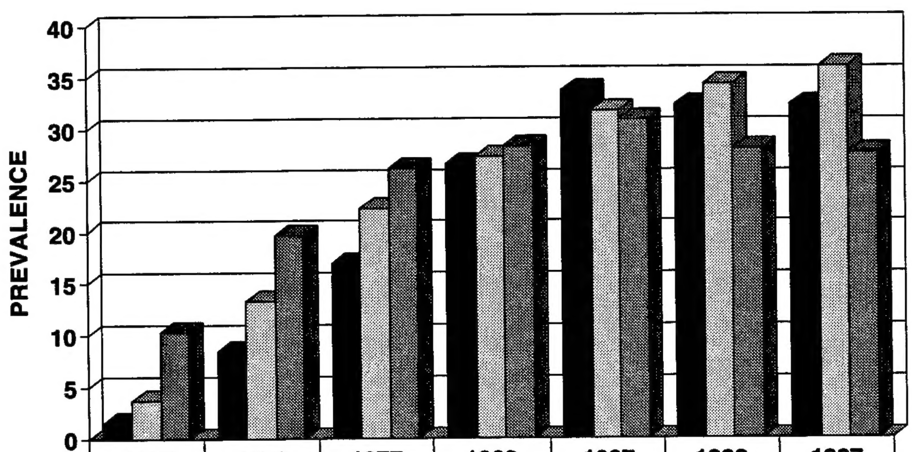
The prevalence rate of contact lens users in the civil airman population by age is presented in Figure 2. The prevalence in older airmen (≥ 40 years of age) has steadily increased during the study period (3.7/1,000 to 34.2/1,000 airmen). In younger airmen (< 40 years of age), the prevalence peaked in 1987 at 36.6/1,000 airmen and then declined to 25.7/1,000 airmen in 1997.

Airmen with the pathology code for orthokeratology are presented in Figure 3. The use of orthokeratology increased in civil airmen during the period 1987-97, particularly among first-class airmen. In 1997, there were 56 first-class, 12 second-class, and 2 third-class airmen who carried pathology code 158. The total frequency of airmen with orthokeratology increased by 23 times by the end of the 10-year period.

During the period 1988-98, the NTSB Accident/Incident Database and FAA Incident Data System had a total of nine reports (7 accidents and 2 incidents) that referenced the use of contact lenses by airmen. Of these, contact lens use was determined to have contributed to six (5 accidents and 1 incident) aviation mishaps.

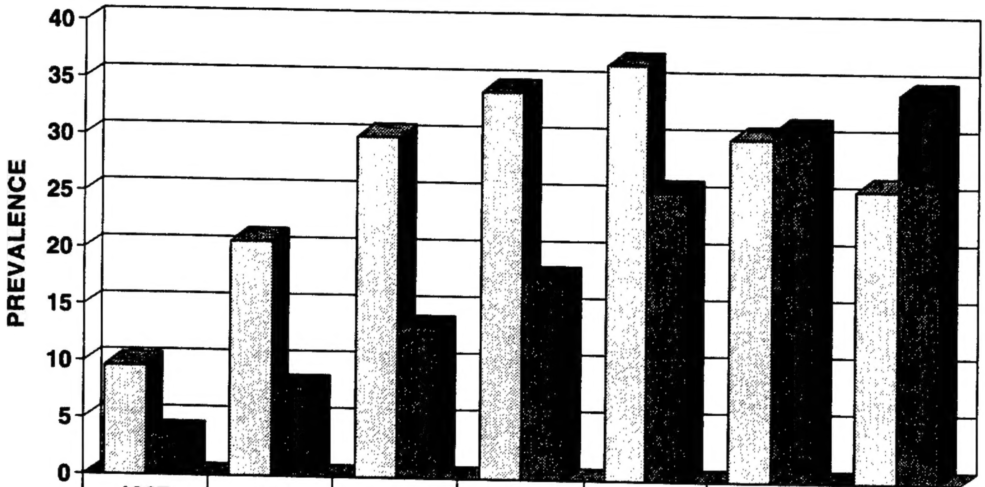
DISCUSSION

Contact lens use by civil airmen has increased substantially over the study period. The prevalence rate for the total airman population increased from 7.3/1,000 in 1967 to 30.8/1,000 in 1997. Several factors may have influenced this increase: better fitting lenses, improved lens designs and materials, simplified lens care systems, improved comfort, and greater acceptance and willingness by eye care practitioners to dispense these lenses.



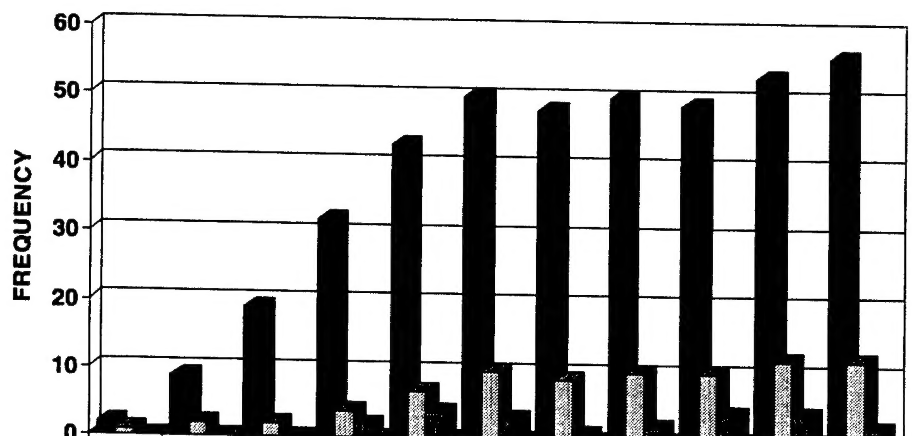
	1967	1972	1977	1982	1987	1992	1997
■ CLASS I	1.6	8.5	16.9	26.5	33.7	32.2	32.3
▨ CLASS II	3.7	13.3	22.2	27.2	31.7	34.3	36
▩ CLASS III	10.3	19.6	26.1	28.2	30.8	27.9	27.5

FIGURE 1. Prevalence of contact lens per 1,000 airmen by class of medical certificate held.



	1967	1972	1977	1982	1987	1992	1997
□ < 40	9.7	20.7	30.1	34.1	36.6	30.2	25.7
■ > = 40	3.7	7.9	13.3	17.7	25.5	31	34.2

FIGURE 2. Prevalence of contact lens users per 1,000 airmen by age.



	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
■ CLASS I	2	9	19	32	43	50	48	50	49	53	56
▨ CLASS II	1	2	2	4	7	10	9	10	10	12	12
■ CLASS III	0	0	0	2	4	3	1	2	4	4	2

FIGURE 3. Frequency of civil airmen with orthokeratology (pathology code 158) by class of medical certificate held.

By class of medical certificate held, the prevalence rates for contact lens use for first-class airmen increased by approximately 20.2 times, second-class by 9.7 times, and third-class by 2.7 times during the study period. Since first- and second-class airmen have stricter distant vision standards and have committed considerable personal resources to their aviation careers, they may be more willing to purchase these devices due to perceived operational advantages. This increased prevalence in the professional pilot population may suggest that these airmen find the use of contact lenses advantageous in the more physiologically stressful and visually demanding cockpit environment. Since the distant vision requirements of a third-class medical certificate is less restrictive than those of a first- or second-class certificate and the physiological and visual environment less demanding, private pilots may not have the same motivation to use these specialty devices.

The older airman population (≥ 40 years of age) had a substantially higher increase (3.5 times) in the prevalence of contact lens use than younger airmen during the study period. This finding differs from that of optical industry demographics, which estimates that 80% of the contact lens wearers are between 18 and 44 years of age (16). This increased prevalence in older contact lens wearers may be partially due to an overall decline in younger pilots entering civil aviation. The average age of the civil airman population has increased from 35.5 years in 1967 (17) to 43.2 years in 1997 (3). Older pilots who have maintained an active aeromedical certificate for many years may continue to carry the contact lens pathology code, even if they have discontinued using these devices. The change in 1976 may also not identify younger airmen with contact lenses applying for a medical certificate, since no question regarding contact lens use appeared on the "Application For Airman Medical Certificate" form (FAA Form 8500-8) from 1976 through March 1999. (Note: As a result of an accident involving monovision contact lenses, and at the recommendation of the NTSB, FAA Form 8500-8 was revised in March 1999 to include a specific question regarding the use of contact lenses while flying.)

Ophthalmic lens manufacturers are vigorously marketing new lens designs and specialty contact lenses to the aging "Baby Boomer" population. However, the FAA considers contact lenses to correct presbyopia (e.g., monovision, modified monovision, multifocal contact lenses) unacceptable for aviation duties (14). Additionally, under CFR Part 67, monovision contact lenses are prohibited, since one eye would not meet the visual acuity standard (2), as first- and second-class airmen are required to have 20/20 or better Snellen visual acuity at distance in each eye separately, with or without corrective lenses. A pilot wearing a near-vision correction monovision contact lens will not meet the distant-vision standard for that eye. Unfortunately, not all pilots or eye care practitioners are aware of this restriction. During the aeromedical certification examination, if the pilot is candid about the type of correction utilized in the cockpit, the AME must advise the applicant that the use of monovision contact lenses is not acceptable while flying.

The FAA considers bifocal and multifocal contact lenses to be unacceptable for the correction of presbyopia in the aviation environment due to reported problems and diminished visual performance associated with their use. There are two basic designs used to correct presbyopia, the alternating or translating (bifocal) and simultaneous vision (multifocal) contact lenses. Alternating bifocal lenses have two separate zones, one for distant vision and the other for near vision (see Figure 4). This type of lens must fit precisely to ensure that the lens is in the correct position for each visual task and be able to move freely between these positions (18). In the aviation environment where humidity and oxygen levels are often reduced, this lens design may not perform properly due to decreased lens movement (11,12). If the lens cannot move properly, the wearer may experience discomfort from inadequate tear flow and looking through the line that separates the two zones can scatter the light rays causing glare (19). In addition, these lenses only permit near vision below the straight-ahead position, which is unsuitable for pilots who may be required to see instruments on panels both above and below their line of sight.

Simultaneous vision multifocal contact lenses use various techniques to change the refracting power across the surface of the lens. These lenses focus light from both distant and near objects simultaneously on the retina without any requisite change in the position of the contact lens on the pupil (18,20). When viewing either distant or near objects, there is a blurred image superimposed on a focused image. The brain chooses one image and suppresses the other. There are three types of simultaneous vision contact lenses (see Figure 5).

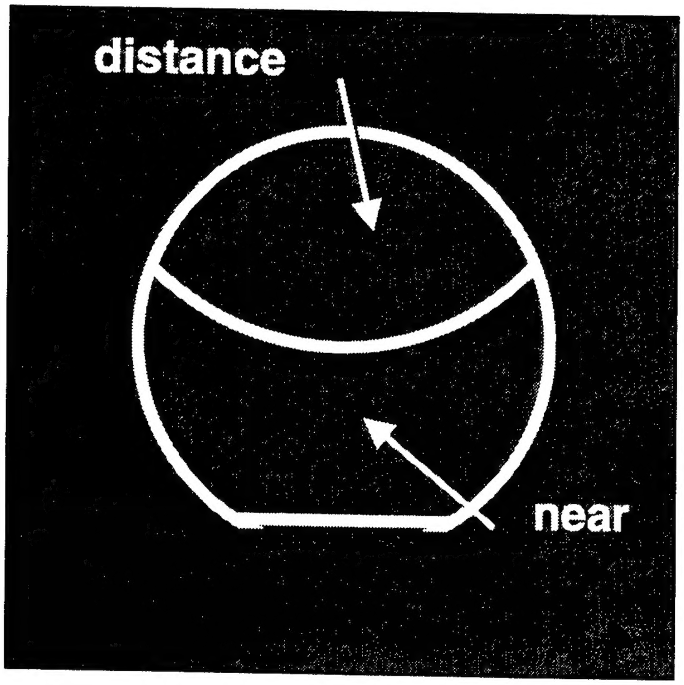


FIGURE 4. An alternating or translating bifocal contact lenses design has two separate zones, one for distant and one for near

- Aspheric contact lenses can have near power in the center of the lens with a continuous change in power from the paracentral area to the mid-periphery for intermediate to distant correction, or vice versa (18,21).
- Concentric contact lenses can have the near power in the center zone of the lens with the distant power in the peripheral zone, or vice versa. The lens has concentric (circles having a common center or curvature) optical centers so that the retinal images from the two zones overlap (18).
- Diffractive contact lenses incorporate a diffraction grating (concentric circular "sawtooth grooves" or echelettes) carved into the base curve or optical zone of the lens. Light entering the lens is equally divided into refracted (front surface) and diffracted (back surface) light for focusing on distant and near objects, respectively. The periphery is optically identical to the center of the lens, allowing the entire pupillary aperture to provide both near and distant vision (22,23,24).

The reported problems with simultaneous vision contact lenses are similar for all of the different designs. These lenses must fit precisely, and the wearer must be able to interpret the appropriate image for the current visual task. Not all individuals can adapt to the performance characteristics of these lenses, and those that do may experience vision performance loss. These include decreased contrast sensitivity (20,25), reduced distant and/or near acuity (18,25), decreased performance at low light levels (25), reduced stereopsis (binocular depth perception) (18,20,25,26), halos and ghost images (19,25), and disability glare (18,20,25). The presence of one or more of these side effects can create difficulties in the flight environment where optimum vision is essential.

Recent studies have indicated that the newer designs and materials may make multifocal contact lenses easier for the patient to adapt to and may be less likely to produce side effects and performance losses (27,28,29). Further research on the applicability of these devices in an aviation environment is needed before the FAA ban on multifocal contact lenses is removed.

In two aviation accidents in which the use of monovision contact lenses was found to be a contributing factor, neither pilot reported the use of monovision lenses to their AME. The first documented mishap occurred in February 1996 when a private pilot wearing monovision lenses flared too late while landing. This resulted in a hard landing and damage to the airplane. However, after changing to bifocal spectacle lenses, significant improvement

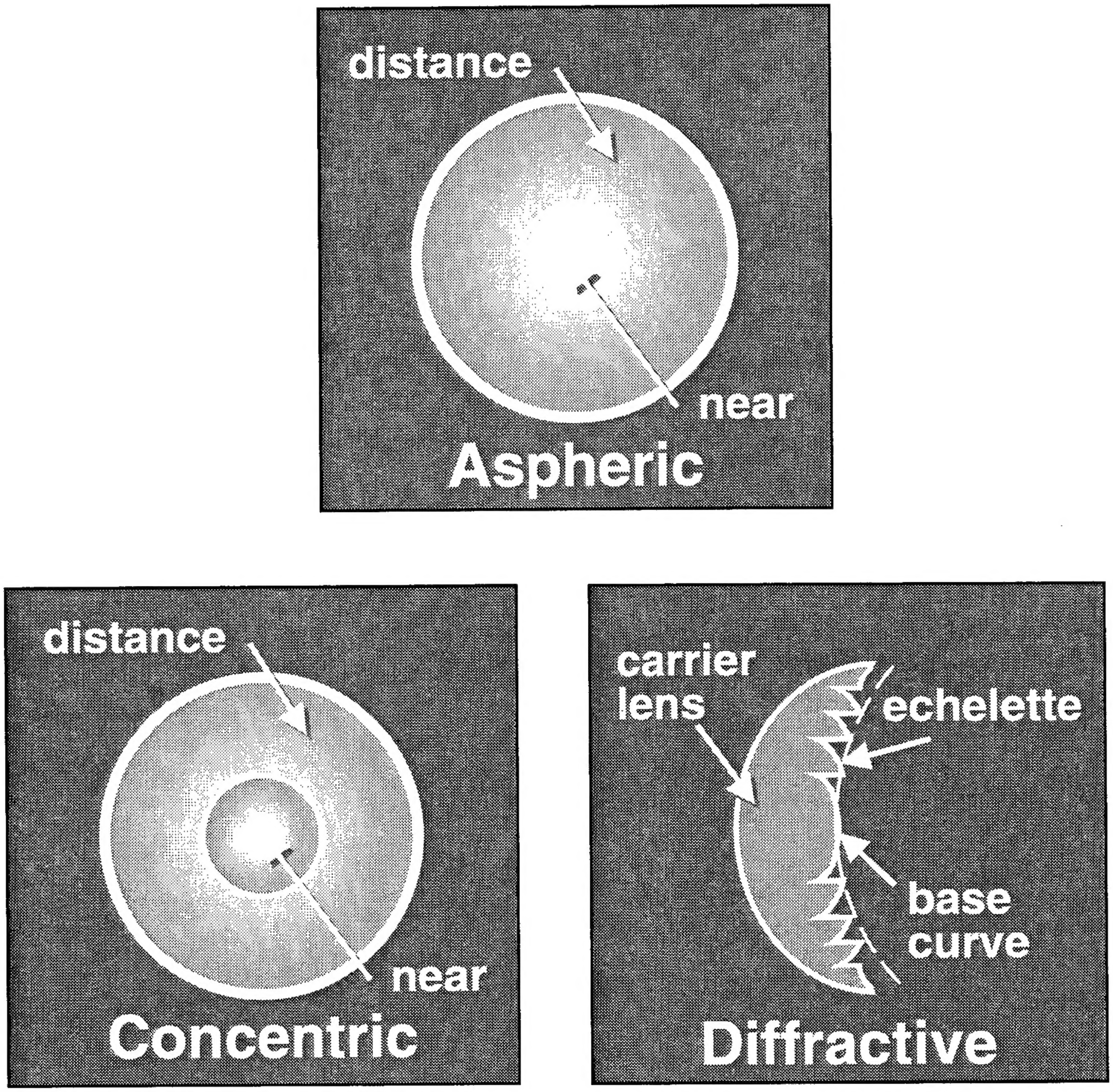


FIGURE 5. Different styles of simultaneous-vision multifocal contact lenses.

occurred in the pilot's landing performance (30). The second mishap occurred in October 1996 when the captain of a McDonnell Douglas MD-88, wearing monovision contact lenses, was unable to overcome his misperception of the airplane's position relative to the runway. According to the NTSB, the pilot's reduced depth perception and contrast sensitivity loss contributed to a short landing where the aircraft struck the approach light structure at the end of the runway, shearing off the main landing gear (31).

The debate on the applicability of monovision or modified monovision contact lenses in civil aviation continues. Many contact lens practitioners have touted the value and usefulness of these modalities to correct presbyopia, since monovision contact lenses have been successfully prescribed for over 30 years. A recent change in FAA policy regarding pilots with monovision refractive surgery may result in a favorable conclusion in any future review of the administrative policy concerning monovision or other bifocal and multifocal contact lenses for civilian pilots. (Note: Pilots with monovision refractive surgery may apply for a waiver to fly without supplemental lenses after a 6-month postoperative period. However, during that 6-month period the pilot must use supplemental ophthalmic lenses to correct the monovision condition (32).)

Contact lens use in the aviation environment does have inherent limitations. Corneal edema has been reported in well-fit contact lens wearers when exposed to altitude hypoxia. During decompression, nitrogen gas may form bubbles beneath a contact lens, affecting vision. The low humidity (10-15%) of an aircraft environment can dehydrate hydrophilic contact lenses, reduce lens movement, and increase conjunctival injection. Lens dehydration has been associated with visual performance (low-contrast acuity) loss (9,10) and can result in contact lens displacement. Pilots have reported the loss or displacement of contact lenses while in flight or had to remove a lens due to discomfort (33). This would be considered a minor inconvenience on the ground but could contribute to a hazardous situation if it were to occur during flight.

Contact lenses are more problematic for older pilots. Normal anatomical and physiological changes with aging (e.g., flaccid eyelids, reduced tears, diminished corneal sensitivity, age-related miosis, and loss of amplitude of accommodation) can affect the wearer's visual performance when using such devices. Furthermore, as people age the use of prescription medication increases, which may alter tear production and complicate contact lens wear. Commonly prescribed medications that may impact visual performance include anticholinergics, antihistamines, antihypertensives, dermatological medications and antidepressants (34).

The other four aviation mishaps involving contact lens use are reviewed below:

- A pilot, who had not slept the night before, reported closing his eyes several times during the flight to alleviate the irritation from his contact lenses. On approach to landing, he closed his eyes and fell asleep. When the pilot awoke, the aircraft was left of the runway and past mid-field. While trying to execute a "go-around," the aircraft struck some trees at the end of the runway (35).
- A pilot reported that his right contact lens was irritating, and he had limited vision in that eye. Although the pilot thought he was too high on final approach and considered a go-around, he chose to land anyway because of the contact lens problem, resulting in a hard landing and minor damage to the airplane (36).
- A pilot who was landing at night asked that the approach lights be turned up to full brightness. The resulting glare was exacerbated by her contact lenses and obstructed her view. The landing was short of the runway, and the aircraft collided with approach lights and an airport boundary fence (37).
- A student pilot's contact lens became dislodged during landing, and the aircraft struck a pile of logs near the taxiway while taxiing to the hanger area (38).

In 1987, the FAA assigned the pathology code 158 to those civil airmen who were using orthokeratology to correct their refractive error. Orthokeratology is the reduction, modification or elimination of refractive error by the programmed use of rigid contact lenses (39). There are many variations in technique, but the usual procedure consists of fitting a patient with a series of contact lenses having a progressively flatter base curve. Once the reduction in refractive error has been attained, a retainer lens must be worn, or the cornea will revert back to its original shape and refractive error (39). In the last 10 years, the use of orthokeratology by civil airmen has significantly increased (23 times), primarily in first-class airmen. The use of orthokeratology by professional pilots may be due to several factors, including an ability to pay for the procedure, and personal reassurance with a method that is reversible and does not have the risk of long-term complications found with laser refractive surgery.

There are approximately 145 million (54.5%) Americans who are dependent on some sort of vision corrective lenses; about 18.3% of these (26.5 million people) wear contact lenses (40). As of December 31, 1997, there were 329,606 (56%) active airmen who had vision restrictions requiring some type of refractive correction for visual deficiencies. About 5.5% of these airmen (18,146) chose contact lenses to correct their defective vision (15). Although the prevalence of contact lens use has increased in the civil aviation population, the majority of airmen requiring distant vision corrections to qualify for an airman medical certificate still use eyeglasses. The considerable difference between the percentage of contact lens use in the general population compared with that of the civil airman population may be explained by a number of factors, including:

1) A bias by airmen as a result of past problems in obtaining waivers to fly with contact lenses;
2) Aging (33% of airmen were >50 years of age in 1997) of the population (41) (Note: About 80% of the contact lens wearers in the general population are between the ages of 18 and 44 (16));
3) The higher frequency of males in the airman population (17:1 ratio of males to females in 1997 (3)). (Note: The American Optometric Association estimates that 66% of contact lenses wearers are females (16).);
4) The FAA restriction that contact lenses be used to correct distant vision only; and
5) The incompatibility of contact lenses with certain flight environments and activities.

Inherent problems of contact lenses in the aviation environment identified in this report could be prevented if pilots take appropriate precautions regarding their lenses. For example, to avoid soft-lens dehydration, low-water content lenses or supplemental re-wetting drops may provide relief from the dry atmospheric conditions of the cockpit; hydrophilic lenses may be worn to minimize the possibility of contact lenses becoming displaced or dislodged during flight; and, pilots should always carry a backup-pair of spectacles in the event contact lenses need to be removed or are lost.

In conclusion, although comprising a small percentage of the total airman population, the number of aviators using contact lenses has increased considerably over the 30-year period. The greatest rate of increase in contact lens use was found in first-class pilots. This suggests that contact lens use satisfies the needs of aviators who must meet a more stringent vision standard and work in the visually demanding environment of air transport aircraft. The study findings indicate that contact lens use was a contributing factor in a small number of aviation accidents. Their increasing popularity in the civil airman population suggests that a vast majority of aviators who use contact lenses find them beneficial in the cockpit environment. Applied appropriately, contact lens use can continue to be a safe alternative for pilots who require refractive correction to satisfy vision requirements for aeromedical certification. Pilots who choose contact lenses should be aware that some types are prohibited, since their use could be a liability when performing certain flight activities. Since new designs, materials, and applications are constantly being developed, contact lens use should be monitored to ensure that these devices continue to provide a safe form of refractive correction in the aviation environment.

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